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35.C11250 CI

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:)	
:	Examiner: D. Schuberg
MANABU KATO)	
:	Group Art Unit: 2872
Appln. No.: 08/951,635)	
:	
Filed: October 17, 1997)	
:	
For: SCANNING OPTICAL APPARATUS)	March 16, 2000

#28
Translation
J. McWilliams
3/23/00

The Assistant Commissioner for Patents
Washington, D.C. 20231

LETTER SUBMITTING SWORN TRANSLATIONS
OF PRIORITY DOCUMENTS

Sir:

In compliance with the provisions of 37 C.F.R. § 1.55, Applicant submits herewith sworn translations of the following priority documents for the subject application:

Country	Appln. No.	Filing Date
Japan	7-066991	February 28, 1995
Japan	8-046741	February 8, 1996

Applicant believes that no fee is required in connection with this paper. However, Applicant authorizes the Assistant Commissioner to charge any fee which may be required in connection with this paper to Deposit Account 06-1205. A duplicate of this paper is enclosed.

Applicant's undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010. All correspondence should be directed to our address given below.

Respectfully submitted,

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684.3135 CI (35.C11250 CI) **PATENT APPLICATION**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	
	:	Examiner: D. Schuberg
MANABU KATO	)	
	:	Group Art Unit: 2872
Appln. No.: 08/951,635	)	
	:	
Filed: October 17, 1997	)	
	:	
For: SCANNING OPTICAL APPARATUS	)	March 9, 2001
	:	

Commissioner for Patents
Washington, DC 20231

CLAIM TO PRIORITY

Sir:

Applicant hereby claims priority under the International Convention and all rights to which he is entitled under 35 U.S.C. § 119 based upon the following Japanese priority applications:

No. 6-239386 filed September 6, 1994;

No. 7-066991 filed February 28, 1995; and

No. 8-046741 filed February 8, 1996.

A certified copy of the first priority document was filed on November 16, 1995, in Application No. 08/522,118 filed August 31, 1995. Certified copies of the remaining priority documents were filed on October 11, 1996, in parent Application No. 08/607,169 filed February 26, 1996.

Applicant's undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010.

All correspondence should continue to be directed to our below-listed address.

Respectfully submitted,

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DSG\tnt

684.3135 CI (35.C11250 CI)

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	
	:	Examiner: D. Schuberg
MANABU KATO	)	
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Appln. No.: 08/951,635	)	
	:	
Filed: October 17, 1997	)	
	:	
For: SCANNING OPTICAL APPARATUS	)	March 9, 2001
	:	

Commissioner for Patents
Washington, DC 20231

LETTER TRANSMITTING SWORN TRANSLATION

Sir:

Applicant is respectfully submitting herewith a sworn translation of Japanese Patent Application No. 6-239386 filed September 6, 1994, from which application the subject application claims priority under 35 U.S.C. § 119. Favorable consideration in this regard is earnestly solicited.

Applicant's undersigned attorney may be reached in our Washington, D.C. office by telephone at (202) 530-1010. All correspondence should continue to be directed to our below-listed address.

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D E C L A R A T I O N

I, Ryuichi YAMADA, a Japanese Patent Attorney registered No. 7898 having my Business Office at Hasegawa Bldg., 4F, 7-7 Toranomon 3-chome, Minato-ku, Tokyo, Japan, solemnly and sincerely declare:

That I have a thorough knowledge of Japanese and English languages; and

That the attached pages contain a correct translation into English of the specification of the following Japanese Application:

APPLICATION NUMBER	DATE OF APPLICATION
239386/1994(Pat.)	6/SEP/1994

Applicant(s)

CANON KABUSHIKI KAISHA

Signed this 22nd day of December, 2000.

Ryuichi YAMADA

PATENT OFFICE

JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy of the following application as filed with this Office.

APPLICATION NUMBER	DATE OF APPLICATION
239386/1994(Pat.)	6/SEP/1994

Applicant(s)

CANON KABUSHIKI KAISHA

06/OCT/1995

Director-General,
Patent Office : YUJI KIYOKAWA (Seal)

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<INTERNATIONAL CLASSIFICATION> G02B 26/10

<TITLE OF THE INVENTION> SCANNING OPTICAL APPARATUS

<NUMBER OF CLAIMS> 5

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<OFFICIAL FEES>
<METHOD> Prepaid
<PREPAY REGISTRATION NO.> 009623
<AMOUNT> 21000

<ARTICLES PRESENTED>
<ARTICLE> Specification 1
<ARTICLE> Drawing(s) 1
<ARTICLE> Abstract 1

<GENERAL POWER NO.> 9004551

[Document]

Specification

[Title of the Invention]

Scanning Optical Apparatus

[Claims]

1. An optical scanning apparatus comprising:

a first optical system for converting luminous flux emitted from a light source to converged luminous flux;

a second optical system for imaging the luminous flux into a linear image extending in a main scanning direction on a deflecting plane of a deflector;

a third optical system for forming an image in a spot shape on a plane to be scanned from the luminous flux deflected by said deflector, wherein said third optical system comprises a single lens, both surfaces of said single lens being aspherical and toric on the main scanning plane, and the following conditions being satisfied, with R_1 denoting the paraxial curvature radius of a deflector side lens surface said single lens, R_2 denoting the paraxial curvature radius of an opposite lens surface of said single lens, Ymax denoting the maximum effective diameter on the main scanning plane of said single

lens, and S_1 and S_2 denoting aspherical-surface amounts from the paraxial lens surfaces at said maximum effective diameter Ymax,

$$0 < R_1 < R_2$$

$$(R_1^2 - Ymax^2)^{1/2} - R_1 < S_1 < 0$$

$$S_2 < (R_2^2 - Ymax^2)^{1/2} - R_2$$

and wherein the following expression is satisfied, with f_t denoting the focal length on the main scanning plane of said third optical system and S_K denoting the distance from said third optical system to the plane to be scanned:

$$0.2 \le 1 - S_K/f_t \le 0.5.$$

2. An optical scanning apparatus according to Claim 1, wherein the curvature on the sub-scanning plane (the plane including the optical axis and perpendicular to the main scanning plane) of at least one lens surface of both surfaces of said single lens constituting said third optical system changes successively within the effective range of said single lens.

3. An optical scanning apparatus according to Claim 1, wherein the symmetrical axis of said second optical system in the main scanning direction is slanted against the normal of said plane to be scanned on the main scanning plane.

4. An optical scanning apparatus according to Claim 1, wherein said third optical system is molded in plastic.

5. An optical scanning apparatus according to Claim 1, wherein said second optical system is molded in glass.

[Detailed Description of the Invention]

[0001]

Field of the Invention

The present invention relates to optical scanning apparatuses, and more particularly, to an optical scanning apparatus best suited to, for example, a laser beam printer (LBP) apparatus and a digital copying machine having an electrophotographic process, wherein luminous flux optically modulated and emitted from light source means is deflected and reflected with an optical deflector including a polygon mirror, and then moves in rapid succession on a plane to be scanned through an image optical system having an fθ characteristics (fθ lens) in order to record image information.

[0002]

Description of the Related Art

In a conventional optical scanning apparatus of a laser beam printer apparatus or the like,

luminous flux optically modulated and emitted from a light source according to an image signal is periodically deflected with an optical deflector including, for example, a polygon mirror, and then is converged on a surface of a photosensitive recording medium (photosensitive drum) in a spot shape with an image optical system having fθ characteristics. The surface is optically scanned to record image.

[0003]

Fig. 13 is an outlined cross section of a conventional optical scanning apparatus.

[0004]

As shown in Fig. 13, divergent luminous flux emitted from light source means 11 is made almost parallel with a collimator lens 12, is restricted in terms of light energy by an aperture 13, and then is input to a cylindrical lens 14 having a certain refractive power only in the sub-scanning direction. The parallel luminous flux input to the cylindrical lens 14 is output in the main scanning cross section as is, and is converged in the sub-scanning cross section to form almost a line image on the deflection surface (reflection surface) 15a of the optical deflector comprising a polygon mirror.

[0005]

Luminous flux deflected and reflected with the deflection surface 15a of the optical deflector 15

is directed to the surface of a photosensitive drum 18 serving as a plane to be scanned, through an image optical system (fθ lens) 16 having fθ characteristics. As the optical deflector 16 is rotated in the direction indicated by arrow A, the surface of the photosensitive drum 18 is optically scanned and image information is recorded.

[0006]

[Problems to be Solved]

To very precisely record image information in such an optical scanning apparatus, it is required that, over all of the plane to be scanned, field curvature is successfully compensated for, the spot diameter is uniform, and distortion aberration (fθ characteristics) which has a proportional relationship between the angle of incident light and image height is provided. Various optical scanning apparatuses having these optical features or their compensation optical systems (fθ characteristics) have been proposed.

[0007]

As laser beam printers and digital copying machines have been made compact and inexpensive, optical scanning apparatuses are required to be made the same.

[0008]

Various optical scanning apparatus comprising

one fθ lens, which satisfy the demands for satisfactorily compensating for field curvature and for providing fθ characteristics, have been proposed, such as those disclosed in Japanese Examined Patent Publication No. 61-48684, Japanese Unexamined Patent Publication No. 63-157122, Japanese Unexamined Patent Publication No. 4-104213, and Japanese Unexamined Patent Publication No. 4-50908.

[0009]

In Japanese Examined Patent Publication No. 61-48684 and Japanese Unexamined Patent Publication No. 63-157122, a single lens having a concave surface facing an optical deflector is used as an fθ lens to converge parallel luminous flux from a collimator lens on a surface of a recording medium. In Japanese Unexamined Patent Publication No. 4-104213, a single lens having a concave surface facing an optical deflector and a toroidal surface facing an image plane is used as an fθ lens. Luminous flux converted to converged luminous flux by a collimator lens is input to the fθ lens. In Japanese Unexamined Patent Publication No. 4-50908, a single lens having high-order aspherical surfaces is used as an fθ lens. Luminous flux converted to converged luminous flux by a collimator lens is input to the fθ lens.

[0010]

However, the optical scanning apparatus

disclosed in Japanese Examined Patent Publication No. 61-48684 still has field curvature in the sub-scanning direction. The apparatus also has a long focal length fθ which is equal to the distance from the fθ lens to the plane to be scanned, because parallel luminous flux forms an image on the plane to be scanned, making it difficult to configure a compact optical scanning apparatus.

[0011]

Since the optical scanning apparatus disclosed in Japanese Unexamined Patent Publication No. 63-157122 has an fθ lens with a thick wall, it is difficult to mold the lens, thereby increasing the cost.

[0012]

The optical scanning apparatus disclosed in Japanese Unexamined Patent Publication No. 4-104213 still has distortion aberration and jitter depending on the polygon surfaces due to an error in mounting the polygon mirror, which serves as an optical deflector.

[0013]

The optical scanning apparatus disclosed in Japanese Unexamined Patent Publication No. 4-50908 has a high-order aspherical fθ lens to successfully compensate for aberrations. However, the spot diameter in the sub-scanning direction tends to change

according to the height of an image because of uneven magnification in the sub-scanning direction between the optical deflector and the plane to be scanned.

[0014]

Accordingly, it is an object of the present invention to provide a compact optical scanning apparatus which compensates for field curvature and distortion aberration, prevents jitter caused by an error in mounting an optical deflector and changes in a spot diameter in the sub-scanning direction according to the height of an image, and is suited to high-resolution printing by appropriately configuring the shape of an fθ lens for cases in which converged luminous flux from a collimator lens forms an image on a plane to be scanned with the fθ lens through the optical deflector.

[0015]

[Means for Solving the Problem]

The present invention provides an optical scanning apparatus comprising:

a first optical system for converting luminous flux emitted from a light source to converged luminous flux;

a second optical system for imaging the luminous flux into a linear image extending in a main scanning direction on a deflecting plane of a deflector;

a third optical system for forming an image in a spot shape on a plane to be scanned from the luminous flux deflected by the deflector, wherein the third optical system comprises a single lens, both surfaces of the single lens being aspherical and toric on the main scanning plane, and the following conditions being satisfied, with R_1 denoting the paraxial curvature radius of a deflector side lens surface the single lens, R_2 denoting the paraxial curvature radius of an opposite lens surface of the single lens, Ymax denoting the maximum effective diameter on the main scanning plane of the single lens, and S_1 and S_2 denoting aspherical-surface amounts from the paraxial lens surfaces at the maximum effective diameter Ymax,

$$0 < R_1 < R_2$$

$$(R_1^2 - Ymax^2)^{1/2} - R_1 < S_1 < 0$$

$$S_2 < (R_2^2 - Ymax^2)^{1/2} - R_2$$

and wherein the following expression is satisfied, with f_t denoting the focal length on the main scanning plane of the third optical system and S_K denoting the distance from the third optical system to the plane to be scanned:

$$0.2 \leq 1 - S_K/f_t \leq 0.5.$$

[0016]

It is further characterized in that the curvature on the sub-scanning plane (the plane

including the optical axis and perpendicular to the main scanning plane) of at least one lens surface of both surfaces of said single lens constituting said third optical system changes successively within the effective range of said single lens; that the symmetrical axis of said second optical system in the main scanning direction is slanted against the normal of said plane to be scanned on the main scanning plane; that said third optical system is molded in plastic; on that said second optical system is molded in glass.

[0017]

[Description of the Preferred Embodiments]

Fig. 1 is a sectional view along the main scanning direction illustrating the main section of an optical scanning apparatus according to a first embodiment of the present invention. Fig. 2 is an enlarged view of the fθ lens shown in Fig. 1.

[0018]

In Fig. 1, there are shown light source means 1, such as that comprising a semiconductor laser.

[0019]

A collimator lens 2 is provided serve as a first optical device, which converts luminous flux (optical beam) emitted from the light source means 1 to converged light, and an aperture stop 3 for arranging the diameter of luminous flux passing

through it.

[0020]

There is also shown a cylindrical lens 4 serving as a third optical device, which has a specified refractive power along the sub-scanning direction. Almost a line image is formed on a deflection plane 5a of the optical deflector 5 (described later) in the sub-scanning cross section with luminous flux passing through the aperture stop 3.

[0021]

The optical deflector 5 serving as a deflection device and comprising, for example, a polygon mirror rotates at a constant speed in the direction indicated with arrow A by driving means (not shown) such as a motor.

[0022]

An fθ lens 6 (image optical system) comprising one lens having the fθ characteristics serving as a third optical device has, as described later, a lens surface Ra facing the optical deflector 5 and a lens surface Rb facing the plane to be scanned, both of which are aspheric, toric surfaces in the main scanning plane. The lens 6 forms an image on a photosensitive drum 8, which is a plane to be scanned, with luminous flux deflected and reflected by the optical deflector 5 according to image

information. The lens 6 also compensates for inclination of the deflection plane of the optical deflector 5.

[0023]

Curvature of the sub-scanning plane (plane including the optical axis and perpendicular to the main scanning plane) of at least one of both lens surfaces Ra and Rb of the fθ lens 6 of the present embodiment changes successively in the effective range of the lens. The symmetrical axis in the main scanning direction of the fθ lens 6 is slanted against the normal line of the plane 8 to be scanned (photosensitive drum surface) on the main scanning plane.

[0024]

In this embodiment, the fθ lens 6 may be molded in plastic. Alternatively, it may be molded in glass.

[0025]

In the present embodiment, luminous flux emitted from the semiconductor laser 1 is converted to the converged light by the collimator lens 2. The luminous flux (luminous energy) is restricted by the aperture stop 3, and is input to the cylindrical lens 4. This incident luminous flux is emitted as is on the main scanning cross section and is converged on the sub scanning cross section, forming a line image

(longitudinal, line image in the main scanning direction) on the deflection plane 5a of the optical deflector. The luminous flux deflected and reflected on the deflection plane 5a of the optical deflector 5 reaches the photosensitive drum 8 through the fθ lens 6. As the optical deflector 5 rotates in the direction indicated by arrow A, the photosensitive drum 8 is optically scanned in the direction indicated by arrow B in order to record images.

[0026]

Means for compensating for distortion aberration (fθ characteristics) and field curvature, according to the present embodiment will be described below. Since luminous flux incident to the fθ lens 6 from the collimator lens 2 through the optical deflector 5 is a converged light, the following condition is required to be satisfied in order to meet the fθ characteristics of the apparatus:

$$0 < R_1 < R_2 \qquad (1)$$

where R_1 and R_2 are paraxial curvature radii of the fθ lens 6 in positional order from the optical deflector on the main scanning plane.

[0027]

This means that the lens surface Ra, which faces the optical deflector 5 of the fθ lens 6, has a convex meniscus shape in the vicinity of the optical axis, and both lens surface Ra and lens surface Rb,

which faces the plane to be scanned, have an aspherical shape. In order to make the spot diameter according to the image height the same in the sub-scanning direction, the lens shape is determined such that the aspherical shape satisfies the following conditions:

$$(R_1{}^2 - Ymax^2)^{1/2} - R_1 < S_1 < 0 \qquad (2)$$

$$(R_2{}^2 - Ymax^2)^{1/2} - R_2 - d < S_2 < (R_2{}^2 - Ymax^2)^{1/2} - R_2 \qquad (3)$$

where Ymax is the maximum effective diameter on the main scanning plane, and S_1 and S_2 are the aspherical-surface amounts from the paraxial lens surface R at the maximum effective diameter Ymax.

[0028]

This is because variation of the F number in the sub-scanning direction according to the image height, namely, variation of the main plane position in the sub-scanning direction, needs to be restricted in order to make the spot diameter according to the image height the same in the sub-scanning direction since the spot diameter ρs in the sub-scanning direction is generally described as below.

$$\rho s = c \lambda Fs$$

where Fs is the F number in the sub-scanning direction, λ is the wavelength of the ray used, and c is the constant.

[0029]

If conditional expression (1) is not satisfied, it becomes difficult to compensate for field curvature, distortion aberration, and so on successfully. If either of conditional expressions (2) and (3) is not satisfied, it becomes difficult to make the spot diameter in the sub-scanning direction the same.

[0030]

In this embodiment, the shape of the fθ lens 6 is configured such that conditional expressions (1), (2), and (3) are satisfied, maintaining field curvature, distortion aberration, and so on at appropriate values and improving the uniformity of the spot diameter in the sub-scanning direction.

[0031]

Next, by referring to Figs. 3 to 5, means for reducing jitter caused by the optical deflector (polygon mirror).

[0032]

When a polygon mirror is used for deflecting luminous flux with the same deflection angle as shown in Fig. 3, the deflection point changes its position back and forth depending on the polygon surface used due to an error caused by engagement with a motor rotation shaft and distance variation from the rotation center to the polygon surface (deflection surface). When light deflected at the polygon surface

5a of the polygon mirror 5 and incident to the fθ lens 6 is parallel, the luminous flux forms the image at the same point on the photosensitive drum, which is the image plane.

[0033]

When light output from the collimator lens has already been converged, however, the luminous flux does not form an image on the same point on the photosensitive drum, causing jitter depending on polygon-mirror surfaces and deteriorating the image.

[0034]

As shown in Fig. 4, the amount of jitter J is expressed by the following expression:

$$J = mh$$

where h is a shift between two bundles of luminous flux deflected at polygon surfaces, and m is the transverse magnification in the main scanning direction.

The transverse magnification m is shown in the following expression:

$$m = 1 - S_K/f_t$$

where f_t is the focal length of the fθ lens 6 in the main scanning direction (on the main scanning plane) as shown in Fig. 5, and S_K is a distance from the fθ lens 6 to the plane 8 to be scanned (photosensitive drum plane).

Therefore the amount of jitter can be

expressed as follows:

$J = (1 - S_K/f_t)h$

[0035]

As shown in Fig. 3, the shift h between the two bundles of luminous flux is determined by the incident angle θi of the luminous flux on the polygon surface, the output angle θe from the polygon surface, and the quantity d of eccentricity on the polygon surface. It can be expressed in the following expression.

[0036]

[Eq. 1]

$$h = (d\sin(\theta e - \theta i))/(\cos\theta e \cos(\theta e - \theta i)/2))$$
$$= d \times g(\theta i, \theta e)$$

Since the above described parameters fall in a limited range, the shift h ranges from 0.02 to 0.04.

[0037]

Generally, jitter becomes noticeable for eyes when the distance between two dots on an image shift half or more of a dot. In an optical scanning apparatus of a laser beam printer having a resolution of 600 dpi, for example, jitter becomes noticeable when the amount of jitter reaches the following value or more.

$J = 25.4/600/2 = 0.02$ mm

Therefore, in order to form a high-quality image, the transverse magnification m in the main

scanning direction shall be limited to 0.5 or less according to the following expressions.

$J = mh$

$0.02 \geq m \times 0.04$

$m \leq 0.5$

[0038]

If the transverse magnification m in the main scanning direction becomes small, however, the distance S_K between the fθ lens 6 and the plane 8 to be scanned becomes long, so that the apparatus cannot be made compact. To meet these two opposing conditions, the refractive power of the fθ lens 6 and that of the collimator lens 2 are determined such that the transverse magnification m in the main scanning direction satisfies the following condition, allowing a compact optical scanning apparatus having reduced jitter caused by an error in mounting the polygon mirror (optical deflector) 5 to be implemented:

$0.2 \leq m \leq 0.5$

Namely,

$0.2 \leq 1-S_K/f_t \leq 0.5 \qquad (4)$

[0039]

If the upper limit of the conditional expression (4) is exceeded, jitter becomes noticeable, deteriorating the quality of an image. If the value is below the lower limit of the expression (4), the distance between the fθ lens 6 and the plane 8 to be

scanned becomes long, making the apparatus large.

[0040]

In this embodiment, the fθ lens 6 is configured with an aspherical surface being expressed by a function having up to a term of tenth degree in the main scanning direction and a spherical surface changing successively in the height direction of an image in the sub-scanning direction. When the intersection between the fθ lens 6 and the optical axis is set to the origin and the optical axis is assumed to be the X-axis, the axis perpendicular to the optical axis on the main scanning plane the Y-axis, and the axis perpendicular to the optical axis on the sub- scanning plane the Z-axis, for example, the shape of the lens in the generating-line direction corresponding to the main scanning direction can be expressed by the following expression.

[0041]

[Eq. 2]

$$X = (Y^2/R)/(1 + (1 - (1 + K)(Y/R)^2)^{1/2}) + B_4Y^4 + B_6Y^6 + B_8Y^8 + B_{10}Y^{10}$$

where R is curvature radius and K, B_4, B_6, B_8, and B_{10} are aspherical-surface coefficients. The shape of the lens in the meridian-line direction corresponding to the sub-scanning direction (direction perpendicular to the main scanning direction including the optical axis) can be expressed as follows:

[0042]

[Eq. 3]

$$S = (Z^2/r')/(1 + (1 - (Z/r')^2)^{1/2}$$

where

$$r' = r(1 + D_2Y^2 + D_4Y^4 + D_6Y^6 + D_8Y^8 + D_{10}Y^{10}).$$

[0043]

Fig. 7 shows the optical arrangement and the aspherical-surface coefficients of the fθ lens 6 according to this of the present invention. Fig. 9 illustrates the shapes of the aspherical surfaces of the fθ lens 6. In Fig. 10, thick lines indicate aspherical-surface amounts S from the paraxial curvature radius and dotted lines indicate the values of $(R^2 - Ymax^2)^{1/2} - R$.

[0044]

In this embodiment, the paraxial curvature radius R, the aspherical-surface amount S, and the values of $(R^2 - Ymax^2)^{1/2} - R$ of the fθ lens 6 are described below which satisfy the conditional expressions (1) to (3).

$R_1 = 65.22$

$R_2 = 150.03$

$S_1 = -9.44$

$S_2 = -7.97$

$(R_1{}^2 - Ymax^2)^{1/2} - R_1 = -14.50$

$(R_2{}^2 - Ymax^2)^{1/2} - R_2 = -6.00$

[0045]

Fig. 11 is an aberration view showing field curvature and distortion aberration in this embodiment. It is understood from this figure that the aberrations have been compensated for to the level at which there is no practical problem. Changes in the spot diameter in the sub-scanning direction due to the image height can also be restricted to 10 μm or less.

[0046]

In this embodiment, the focal length f_t of the fθ lens 6 in the main scanning direction is set to 213.7 mm, the distance S_K from the fθ lens 6 (plane from which luminous flux is output of the fθ lens 6) to the plane 8 to be scanned (photosensitive drum surface) 111.5 mm, and the transverse magnification m in the main scanning direction 0.478 as described below in order to satisfy the conditional expression (4). This reduces jitter caused by an error in mounting the polygon mirror (optical deflector).

$$m = 1 - S_K/f_t = 1 - 111.5/213.7 = 0.478$$

[0047]

Since the shift h between the two bundles of luminous flux in the present embodiment has the following value when the incident angle θi of the flux to the polygon plane 5a is -90 degrees, the output angle θe of the flux is 45 degrees, and the quantity d of eccentricity on the polygon plane 5a is 15 μm, the

jitter amount J has the value described below.

[0048]

[Eq. 4]

$$h = (d\sin(\theta e - \theta i))/(\cos\theta e \cos((\theta e - \theta t)/2))$$
$$= 0.039 \text{ mm}$$
$$J = mh = 0.0186 \text{ mm}$$

Thus, jitter can be restricted to the level at which it is not noticeable to the eye.

[0049]

As described above, the shape and optical arrangement of the fθ lens 6 is appropriately configured in the present embodiment so that field curvature and distortion aberration are successfully compensated for and problems related to jitter caused by an error in mounting the optical deflector and related to changes in the spot diameter in the sub-scanning direction according to the image height are solved when converged light from the collimator lens forms an image on the plane to be scanned with one fθ lens through the optical deflector.

[0050]

Fig. 6 shows a cross section (main-scanning cross section) of the main section of an optical system in the main scanning direction according to a second embodiment of the present invention. In Fig. 6, the same elements as those shown in Fig. 1 have the same symbols.

[0051]

The present embodiment differs from the first embodiment, described above, in that a fθ lens 26 having a thinner center thickness in the optical-axis direction than the fθ lens 6. Other configurations and optical operation are almost the same.

[0052]

Fig. 8 shows the optical arrangement and the aspherical-surface coefficients of the fθ lens 26 according to the second embodiment of the present invention. Fig. 10 illustrates the aspherical-surface amounts of the fθ lens 26. In Fig. 10, thick lines indicate an aspherical-surface amount S from the paraxial curvature radius and dotted lines indicate the values of $(R_2 - Ymax^2)^{1/2} - R$.

In the second embodiment, the paraxial curvature radius R, the aspherical-surface amount S, and the values of $(R_2 - Ymax^2)^{1/2} - R$ of the fθ lens 26 are described below and they satisfy the conditional expressions (1) to (3).

$R_1 = 45.16$

$R_2 = 68.96$

$S_1 = -20.24$

$S_2 = -14.61$

$(R_1{}^2 - Ymax^2)^{1/2} - R_1 = -26.23$

$(R_2{}^2 - Ymax^2)^{1/2} - R_2 = -14.27$

[0054]

Fig. 12 is an aberration view showing field curvature and distortion aberration of the second embodiment. It is understood from this figure that the aberrations have been compensated for to the level at which there is no practical problem. Changes in the spot diameter in the sub-scanning direction due to the image height can also be restricted to 10 μm or less.

[0055]

In the second embodiment, when the focal length f_t of the fθ lens 26 in the main scanning direction is set to 226.0 mm, and the distance S_K from the fθ lens 26 to the plane 8 to be scanned (photosensitive drum surface) is set to 111.5 mm, the transverse magnification m is as described below.

$$m = 1 - S_K/f_t = 1 - 111.5/226.0 = 0.493$$

This value satisfies the conditional expression (4) as in the first embodiment, and jitter caused by an error in mounting the optical deflector (polygon mirror) is restricted to a level at which it is not noticeable to the eye.

[0056]

As described above, the shape and optical arrangement of the fθ lens 26 is appropriately configured in the present embodiment so that field curvature and distortion aberration are successfully compensated for and problems related to jitter caused

by an error in mounting the optical deflector and related to changes in the spot diameter in the sub-scanning direction according to the image height are solved, as described in the first embodiment.

[0057]

According to this embodiment, since the center thickness of the fθ lens is thin in the optical-axis direction and its refractive power is restricted by inputting converged luminous flux to the fθ lens, reducing the molding tact time for the fθ lens and implementing the inexpensive optical scanning apparatus.

[0058]

[Advantageous Effects]

According to the present invention, the factors related to the fθ lens 6, such as the paraxial curvature radius in the main scanning direction, aspherical-surface amount, focal length, and distance to the plane to be scanned, are appropriately set as described above when converged luminous flux from the collimator lens forms an image on the plane to be scanned with one fθ lens through the optical deflector so that field curvature and distortion aberration are successfully compensated for and effects of jitter caused by an error in mounting the optical deflector and of changes in the spot diameter in the sub-scanning direction according to the image height are

minimized, allowing the compact optical scanning apparatus suited to high-precision printing to be implemented.

[Brief Description of the Drawings]

Fig. 1 is a cross section of the main section in the main scanning direction of an optical scanning apparatus according to a first embodiment of the present invention.

Fig. 2 is an enlarged view of the fθ lens shown in Fig. 1.

Fig. 3 is an enlarged view of a part of the optical deflector shown in Fig. 1.

Fig. 4 is a view showing correlation between jitter and a shift between two bundles of luminous flux according to the first embodiment of the present invention.

Fig. 5 is a view illustrating the positional relationship in the area from the optical deflector to the plane to be scanned according to the first embodiment of the present invention.

Fig. 6 is a cross section of the main section in the main-scanning direction of an optical scanning apparatus according to a second embodiment of the present invention.

Fig. 7 shows aspherical-surface coefficients of the fθ lens and data for the optical arrangement in

the first embodiment of the present invention.

Fig. 8 shows aspherical-surface coefficients of the fθ lens and data for the optical arrangement in the first embodiment of the present invention.

Fig. 9 illustrates the shapes Of the aspherical surfaces of the fθ lens according to the first embodiment of the present invention.

Fig. 10 illustrates the shapes of the aspherical surfaces of the fθ lens according to the second embodiment of the present invention.

Fig. 11 illustrates field curvature and distortion aberration according to the first embodiment of the present invention.

Fig. 12 illustrates field curvature and distortion aberration according to the second embodiment of the present invention.

Fig. 13 is a general view showing the main section of the optical system of a conventional optical scanning apparatus.

[Document]

Abstract

[Abstract]

[Object]

To provide a scanning optical apparatus wherein a curvature of field, a distortion and/or the like is satisfactorily corrected, and influence of jittering attributable to a mounting error of a light deflector and/or change of a spot diameter in a sub-scan direction depending on an image height or the like can be suppressed.

[Structure]

An optical scanning apparatus comprising a first optical system for converting luminous flux emitted from a light source to converged luminous flux; a second optical system for imaging the luminous flux into a linear image extending in a main scanning direction on a deflecting plane of a deflector; a third optical system for forming an image in a spot shape on a plane to be scanned from the luminous flux deflected by the deflector, wherein paraxial curvature radii aspherical-surface amounts, focal length, a distance to the surface to be scanned and the like are properly set.

[Selected Figure]

Figure 1

FIG. 1

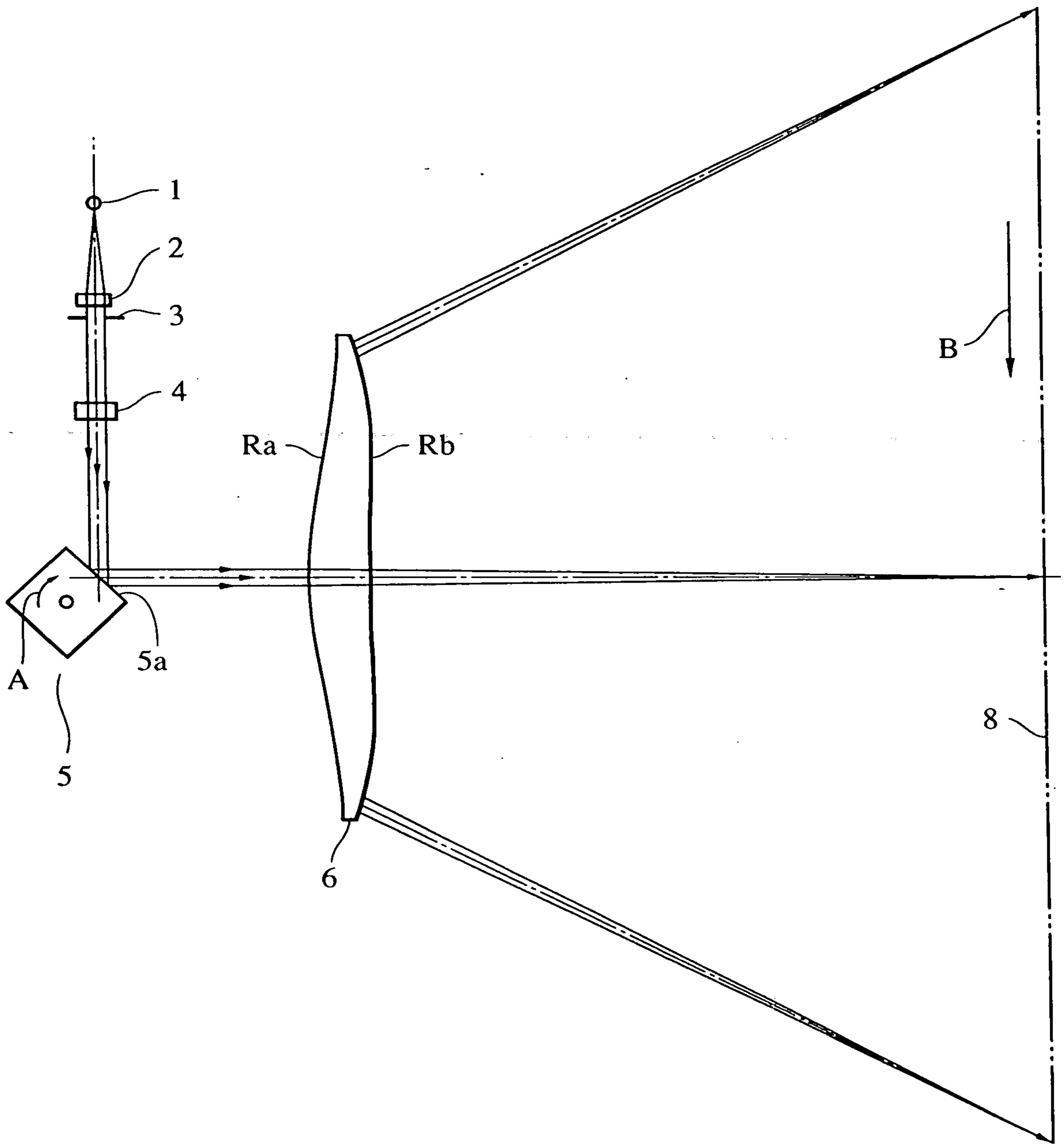


FIG. 2

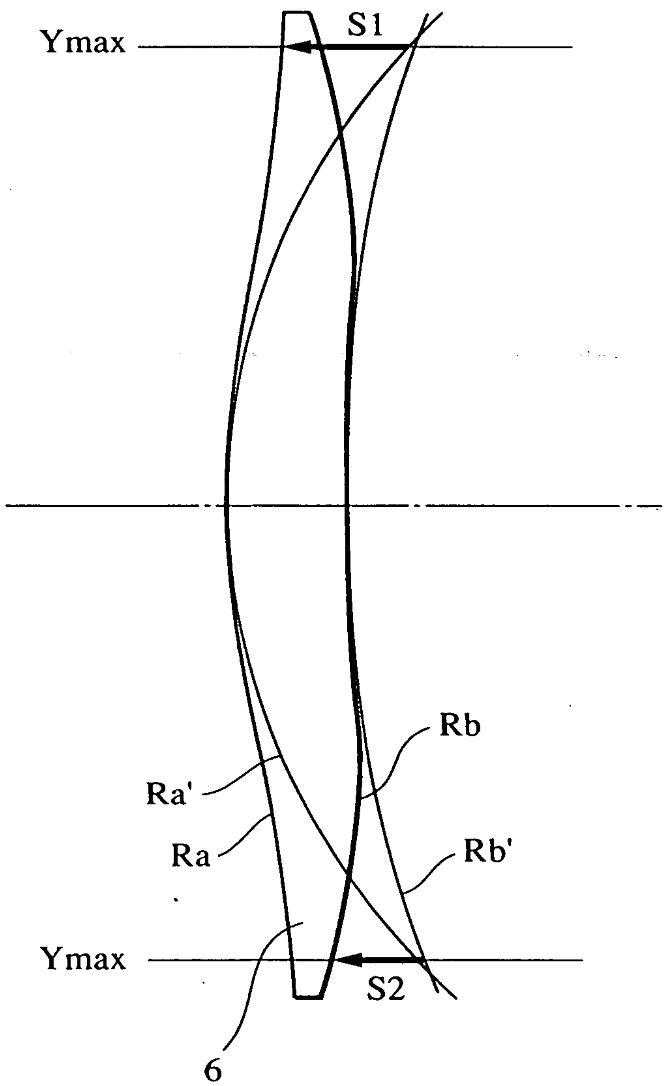


FIG. 3

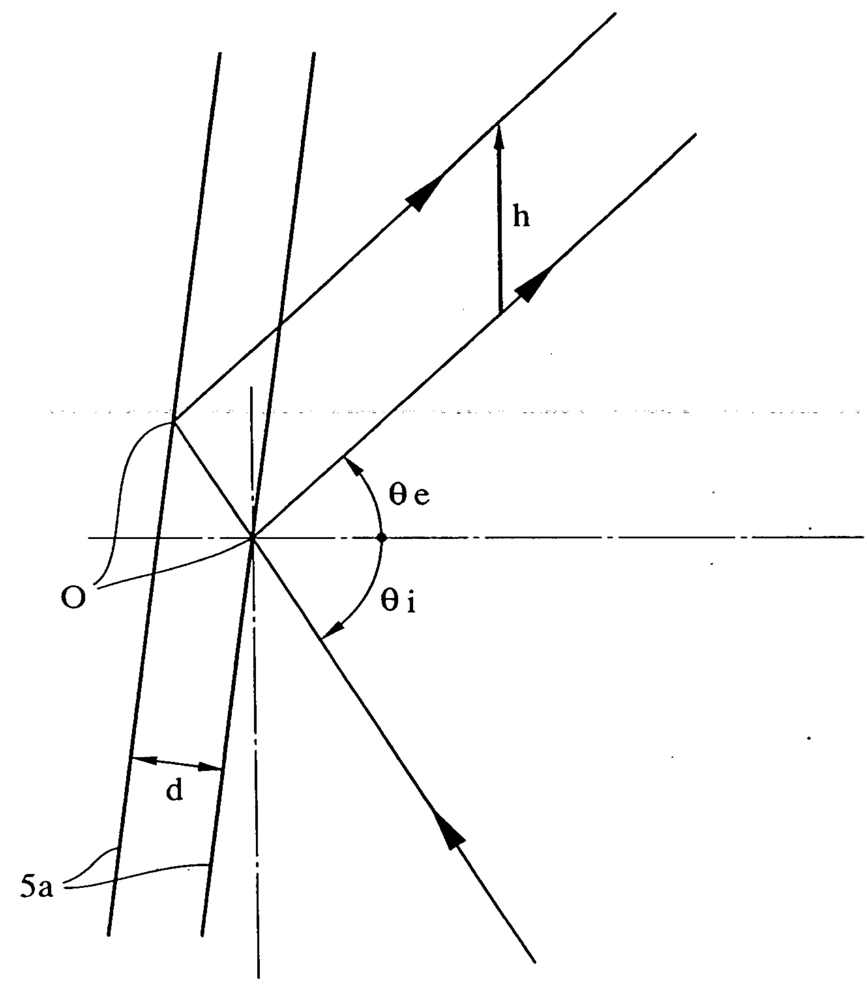


FIG. 4

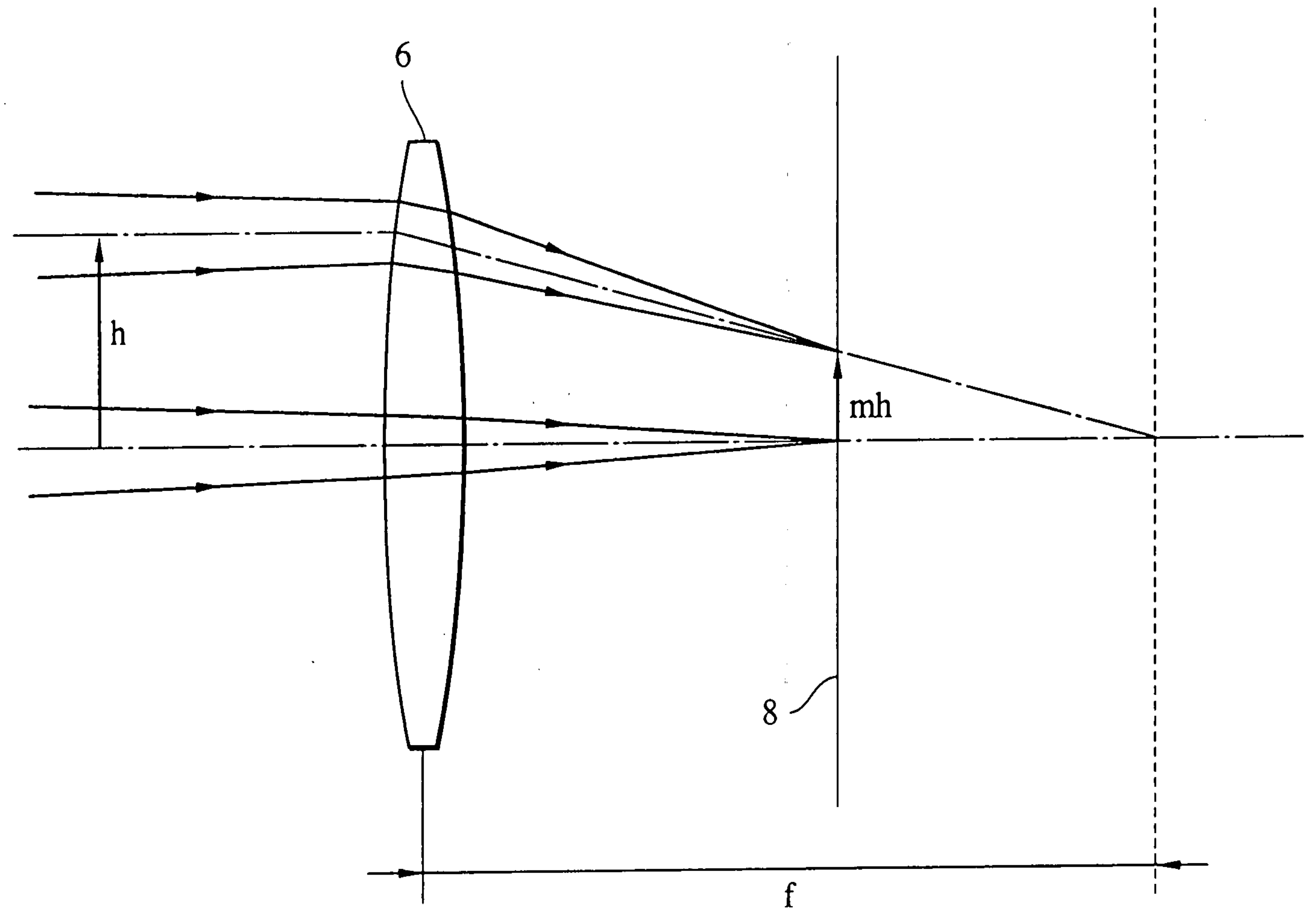


FIG. 5

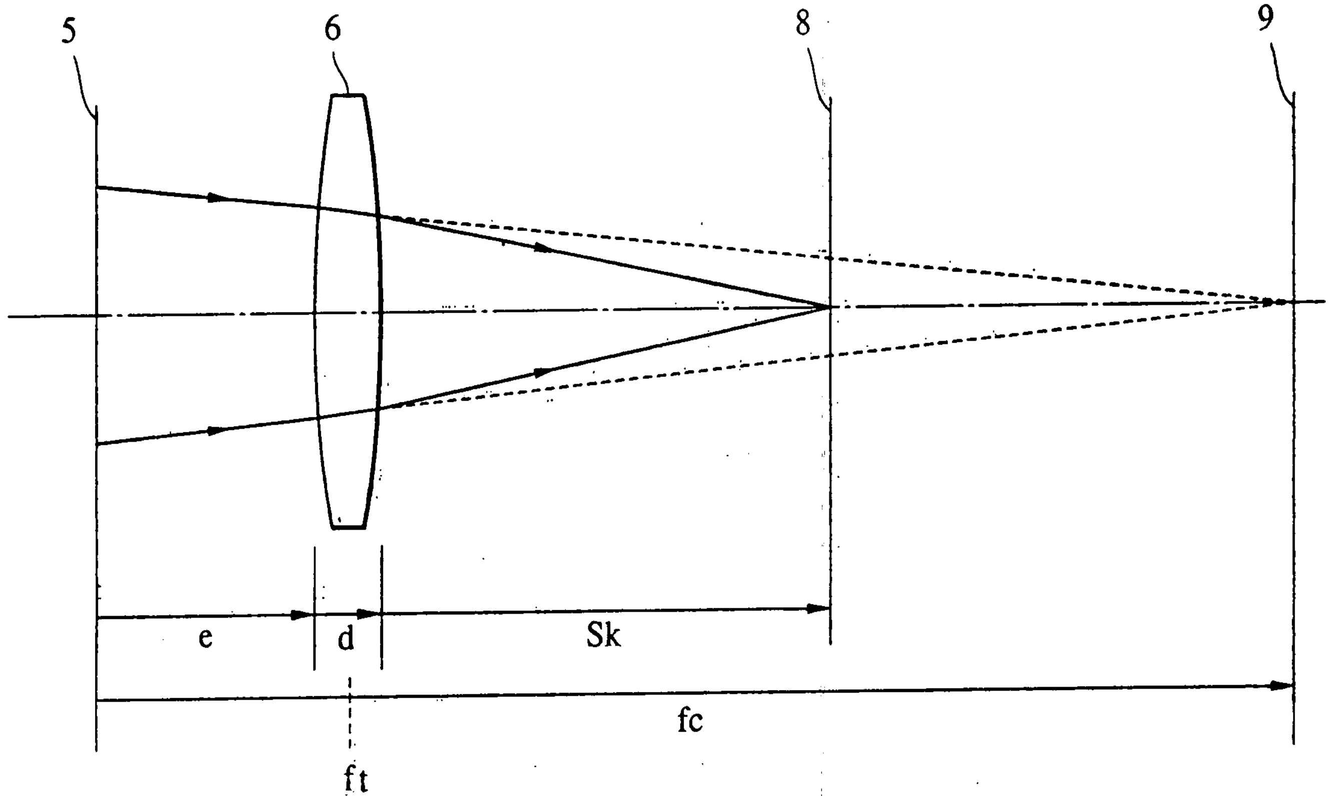


FIG. 6

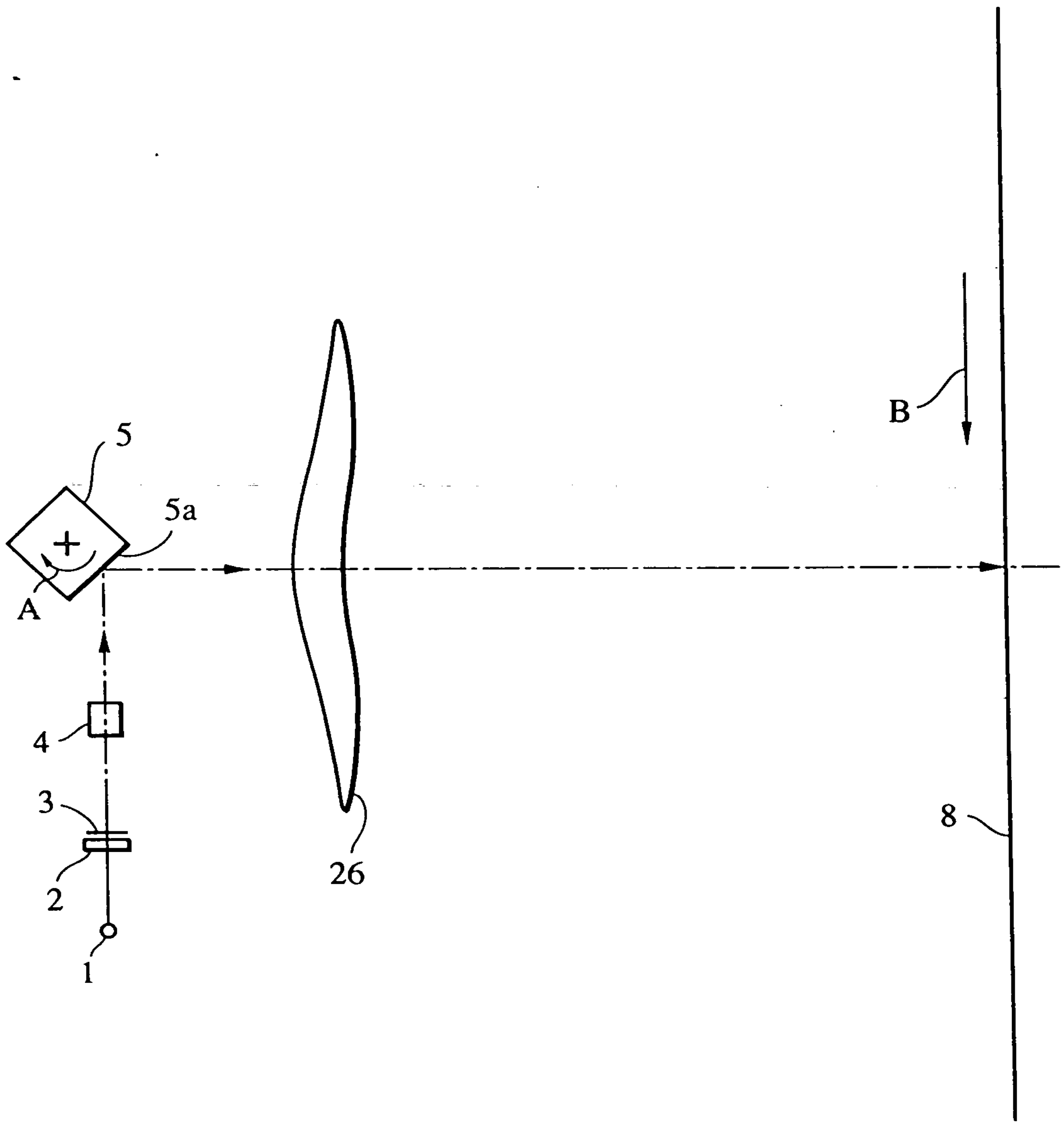


FIG. 7

			fθ-LENS SHAPE		
				FIRST SURFACE	SECOND SURFACE
WAVELENGTH	λ(nm)	780			
fθ-LENS REFRACTIVE INDEX	n	1.519	R	6.5220E+01	1.5003E+02
POLYGON-MIRROR INCIDENT ANGLE	θi	-90	K	-1.6158E+01	-1.0331E+02
POLYGON-MIRROR MAXIMUM OUTPUT ANGLE	θmax	45	B4	-9.2497E-07	-2.2461E-06
DISTANCE BETWEEN POLYGON-MIRROR AND fθ LENS	e	36	B6	-9.6904E-12	6.7766E-10
fθ-LENS CENTER THICKNESS	d	10	B8	8.8464E-14	-3.0973E-13
DISTANCE BETWEEN fθ LENS AND PLANE TO BE SCANNED	Sk	111.5	B10	-4.7942E-18	7.9836E-17
fθ-LENS MAXIMUM EFFECTIVE DIAMETER	Ymax	42	r	-2.8624E+01	-1.1796E+01
fθ-LENS FOCAL LENGTH	ft	213.7	D2E		2.8072E-04
COLLIMATOR CONVERGENCE DEGREE POLYGON-MIRROR NATURAL CONVERGENCE POINT	fc	317.3	D4E		-4.4502E-07
			D6E		3.1689E-10
			D8E		-1.2305E-13
			D10E		1.9682E-17
			D2S		2.6717E-04
			D4S		-4.3192E-07
			D6S		3.0311E-10
			D8S		-1.1220E-13
			D10S		1.6618E-17

FIG. 8

			fθ-LENS SHAPE		
				FIRST SURFACE	SECOND SURFACE
WAVELENGTH	λ(nm)	780			
fθ-LENS REFRACTIVE INDEX	n	1.519	R	4.5160E+01	6.8961E+01
POLYGON-MIRROR INCIDENT ANGLE	θi	-90	K	-1.0754E+01	-2.6413E+01
POLYGON-MIRROR MAXIMUM OUTPUT ANGLE	θmax	45	B4	-1.2518E-06	-2.5621E-06
DISTANCE BETWEEN POLYGON-MIRROR AND fθ LENS	e	32.1	B6	-4.0553E-11	7.2312E-10
fθ-LENS CENTER THICKNESS	d	8	B8	4.3592E-14	-3.8529E-13
DISTANCE BETWEEN fθ LENS AND PLANE TO BE SCANNED	Sk	111.5	B10	5.6642E-18	7.8312E-17
fθ-LENS MAXIMUM EFFECTIVE DIAMETER	Ymax	42	r	-2.4679E+01	-1.0520E+01
fθ-LENS FOCAL LENGTH	ft	226	D2E		4.7160E-04
COLLIMATOR CONVERGENCE DEGREE POLYGON-MIRROR NATURAL CONVERGENCE POINT	fc	302	D4E		-6.4930E-07
			D6E		2.9390E-10
			D8E		-9.1385E-16
			D10E		-2.4537E-17
			D2S		4.3627E-04
			D4S		-6.1710E-07
			D6S		2.7131E-10
			D8S		-8.1699E-17
			D10S		-2.0247E-17

FIG. 9

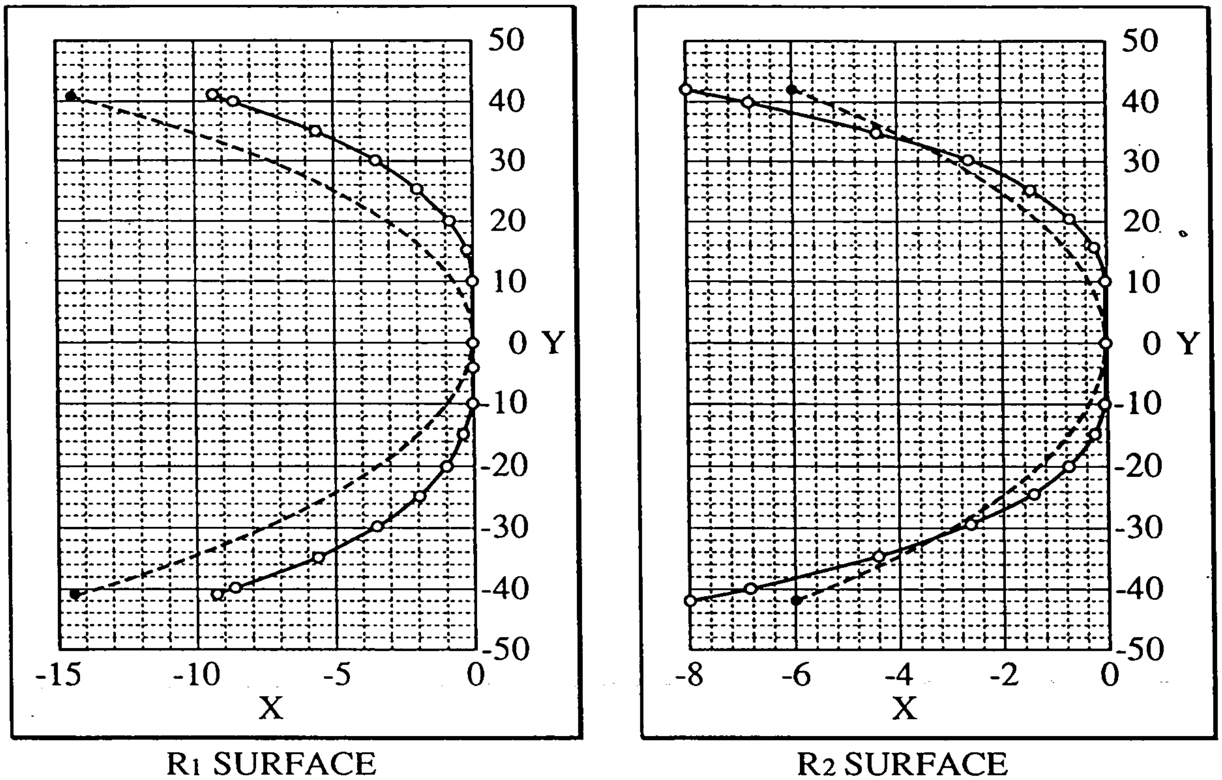

50
40
30
20
10
0 Y
-10
-20
-30
-40
-50
-15
-10
-5
0
X
R1 SURFACE
50
40
30
20
10
0 Y
-10
-20
-30
-40
-50
-8
-6
-4
-2
0
X
R2 SURFACE

FIG. 10

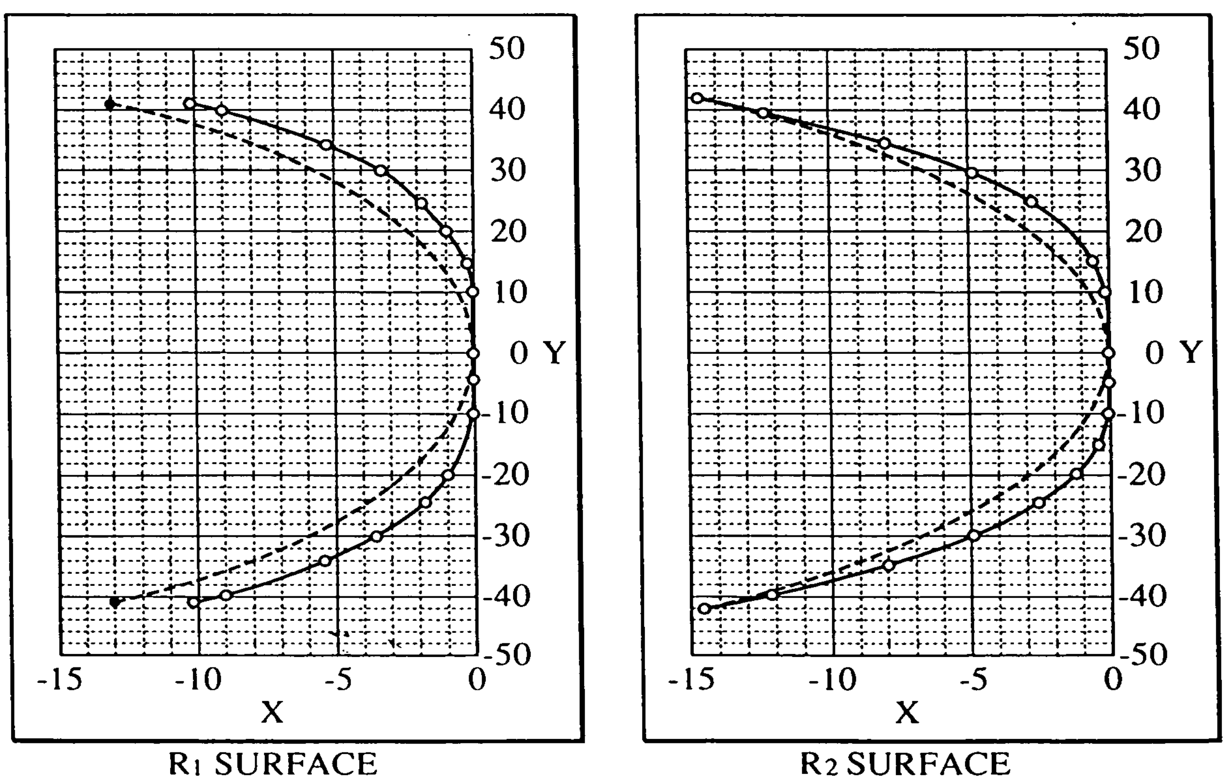
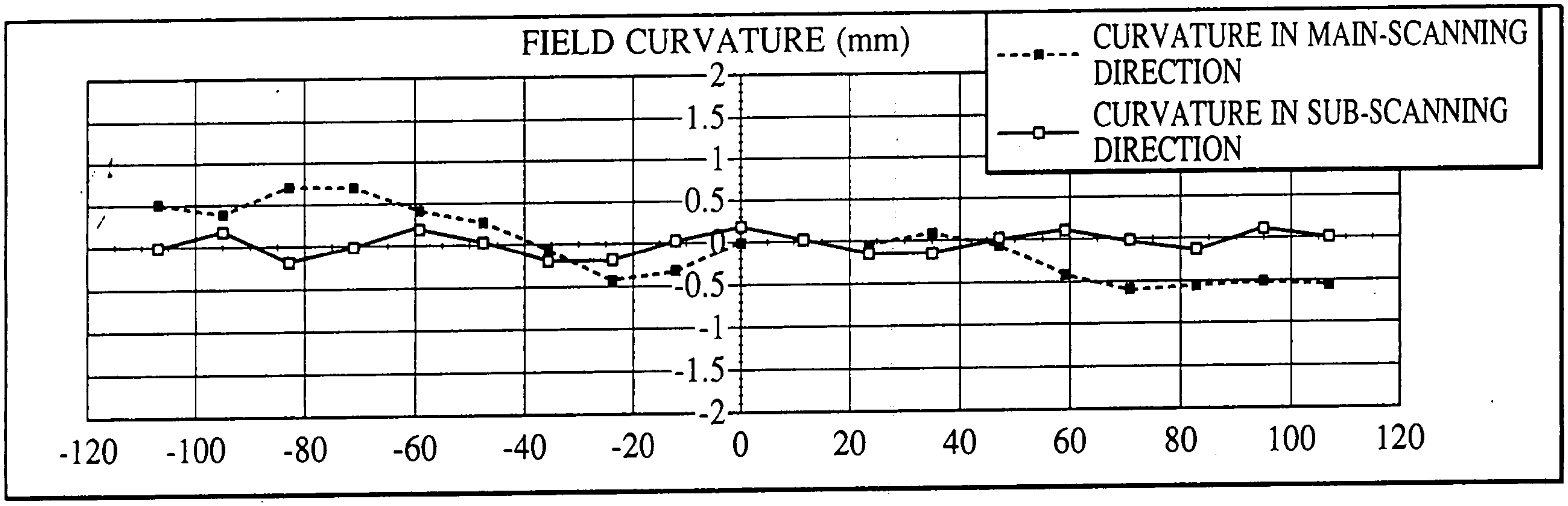

50
40
30
20
10
0 Y
-10
-20
-30
-40
-50
-15
-10
-5
0
X
R1 SURFACE
50
40
30
20
10
0 Y
-10
-20
-30
-40
-50
-15
-10
-5
0
X
R2 SURFACE

FIG. 11


FIELD CURVATURE (mm)
CURVATURE IN MAIN-SCANNING DIRECTION
CURVATURE IN SUB-SCANNING DIRECTION
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120

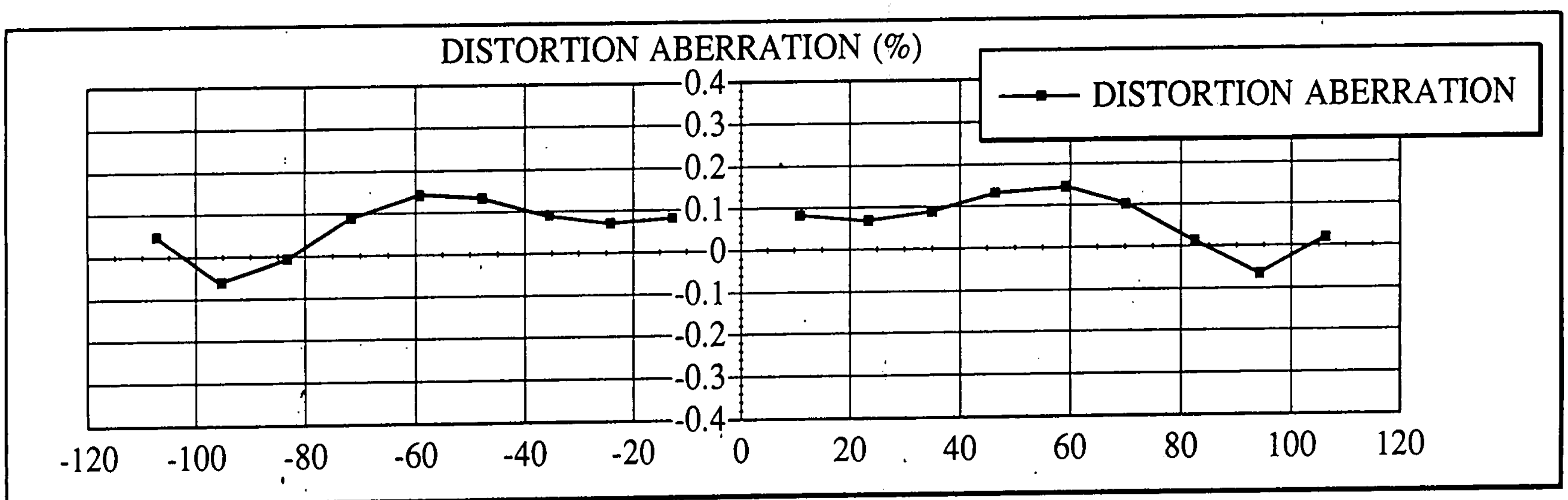
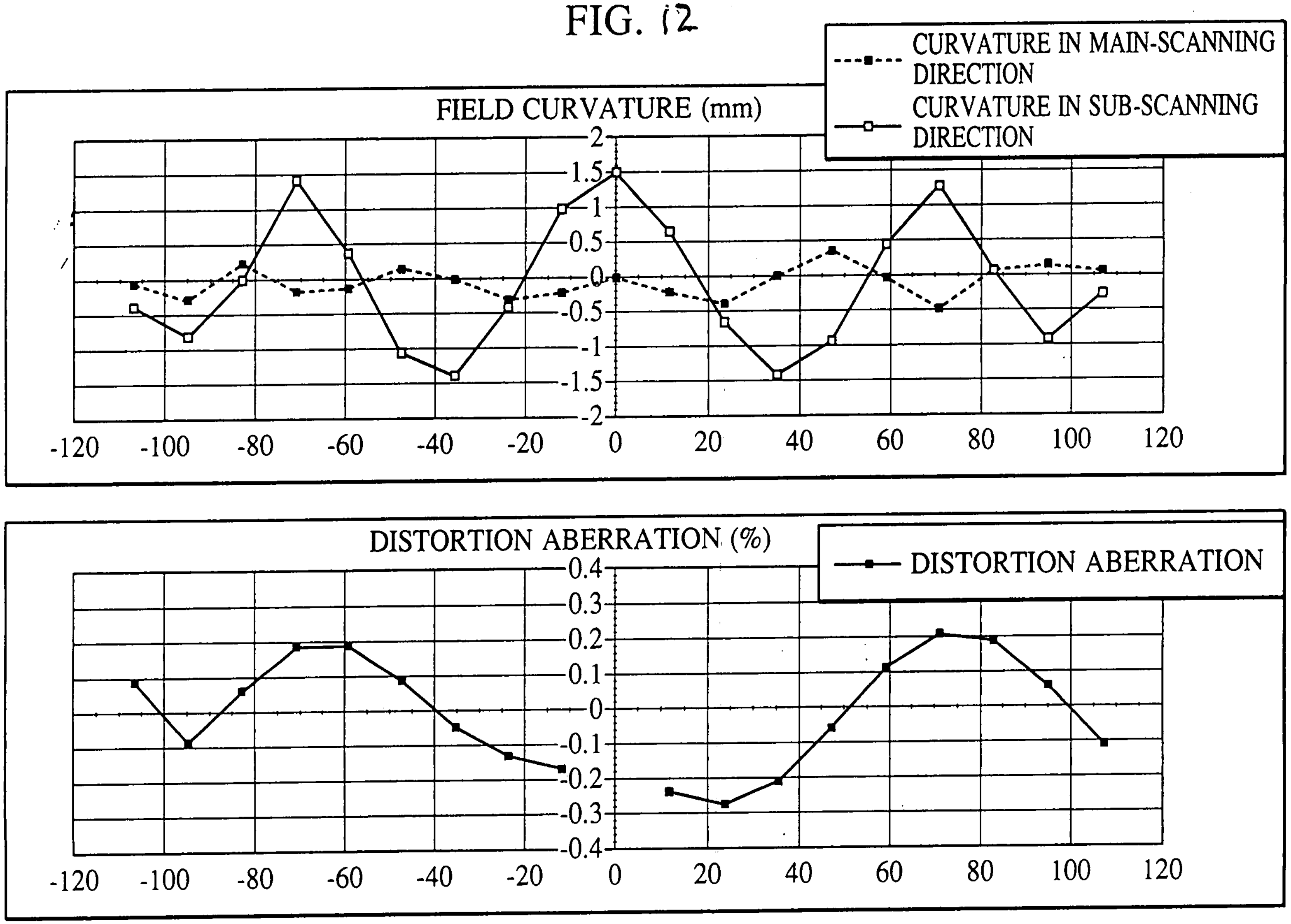

DISTORTION ABERRATION (%)
DISTORTION ABERRATION
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120

FIG. 12



FIELD CURVATURE (mm)
CURVATURE IN MAIN-SCANNING DIRECTION
CURVATURE IN SUB-SCANNING DIRECTION
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
DISTORTION ABERRATION (%)
DISTORTION ABERRATION
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120

FIG. 13